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(54) IMPROVEMENTS IN OR RELATING TO THE PHOTOELECTRIC INSPECTION OF SHEET MATERIALS

(71) We, OMRON TATEISI ELECTRONICS Co., a Japanese Body Corporate, of 10 Hanazono-Tsuchido-cho, UkyoOku, Kyoto-city, Kyoto-prefecture, Japan. do hereby declare

the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a system for the photoelectric defect inspection of sheet materials. The invention is applicable, for instance, to apparatus for photoelectrically detecting such defects as wrinkles, protuberances or sticking substances, etc., in the manufacture of paper, fabrics and various filmy materials, and resultantly removing defective sheets from piles of cut sheets, by means of the detecting signal.

The present invention seeks to provide a method and apparatus for thoroughly inspecting sheet materials for defects such as wrinkles, protuberances or foreign bodies adhering thereto.

In this specification, the word "lengthwise" or "lengthways" is used in the sense of "of or in the direction of movement" of sheet materials, and the wordd "widthwise" or "widthways" in the sense of "of or in the direction perpendicular to that of movement" of sheet materials.

In this specification, the expression "sheerly close" is used in the sense of "close to the sheet material so that a small defect of the sheet such as wrinkles, protuberances or sticking substances can be shot out by the light beam".

Conventionally, defects such as wrinkles, protuberances or foreign bodies on sheet materials have been inspected by, for instance, a detecting arm touching lightly on the surface of the moving sheet, the arm being connected to a transducer for generating a detection signal. Such a conventional method has the drawback that lengthwise defects, i.e. defects lying parallel to the direction of movement of the sheet material, can hardly be detected on account of the gradual movement of the detecting arm. Moreover, such a mechanical detection means has a low sensitivity.

According to the invention there is provided an apparatus for the photoelectric defect inspection of a moving sheet material in which the defects are wrinkles, protuberances or sticking substances, comprising at least one light beam emitting means for emitting a narrow light beam which travels in a direction perpendicular to the direction of movement of the sheet material and sheerly close to the surface thereof; at least one photoelectric transducer for photoelectrically detecting total or partial reflection of the said light beam reflected at defective parts standing out from the surface of the sheet material; and at least one amplifier for amplifying the electric signals from the said photoelectric transducer.

According to the invention there is also provided a method for photoelectric defect inspection of a moving sheet material is which the defects are wrinkles, protuberances or sticking substances, wherein at least one narrow light beam is emitted in a direction perpendicular to the direction of movement of the sheet material and sheerly close to the surface thereof, and wherein light from said light, beam, reflected by defective parts standing out from the surface of the sheet material, is detected.

With a method and apparatus embodying the present invention, a detection signal of adequate amplitude can be obtained whenever a lengthwise defect is detected, thus ensuring an infallible detection.

The said narrow light beam is emitted in the direction perpendicular to the direction of

movement of the sheet material, i.e. widthways thereto, and travels sheerly close across the surface of the sheet material so as to be infallibly intercepted and reflected by any defects such as wrinkles, protuberances or foreign matter adhering to the surface of the material. The light beam thus emitted is reflected by the defective parts in such a manner that any defects intercept and reflect the light beam totally or partly depending on the degree of protrusion of the defects. The said photoelectric transducer means catches such light beam reflection and generates electric signals corresponding to the defects of the sheets material.

In order to emit the narrow light beam to travel very close to the surface and widthways fully across sheet material, a light beam emitted from a light source composed for instance of gas LASER and converging optical means, is preferably employed. The said photoelectric transducer means is for photoelectric detector of changes of the light beam caused by total or partial interception and reflection of the light beam by the defective parts. Accordingly, the transducer can be operated to detect total or partial reflection of the light beam by defective parts. The amplifier is for amplifying the output signal of the photoelectric transducer enabling such performances as to mark the sheet material by ink or to remove sheet material carrying defective parts from a pile of cut sheet. An A.C. amplifier is preferable to a D.C. amplifier for the reason of stable performances.

Specific embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figures 1 to 5 are perspective views respectively showing the principal parts of embodiments of the present invention,

Figure 6 and Figure 8 are side views respectively showing the principal parts of either embodiments and

Figure 7 is a block diagram showing the principal parts of the electric constitution of the examples shown in Figure 6 and Figure 8.

In the embodiment, shown in Figure 1, a sheet material 1 is driven in a direction indicated by arrow "a" by a driving means not shown in the figure while passing over a roller 2. Accordingly, when no defects exist, the surface of the sheet material 1 assumes a part-cylindrical shape on the roller 2. A narrow light beam LW is emitted from a light beam emitting means 6, for instance, gas LASER light source combined with converging optical means, to travel widthways sheerly close to and across the surface of the sheet material 1 at the part where it passes over the roller 2. Above the path of the light beam LW, a photoelectric transducer means 9 is provided consisting of photoelectric transducer elements 91, 92 . . . . 9n arranged in such a position as to cover the light path below. Consequently, when a lengthwise defect 8 such as a wrinkle, a protuberance or an adhering foreign body totally or partly intercepts the light beam LW and thereby reflects at least a portion of the light, the reflected light strikes the nearest photoelectric transducer element of the photoelectric transducer means 9, and causes the said transducer element to generate an electric signal. When a widthwise defect 5 such as a wrinkle, a protuberance or adhering foreign body crosses the path of the light beam LW, the light beam is intercepted for a short time causing a reflection of the light, and causes the transducer means 9 to generate an electric impulse signal.

In the embodiment shown in Figure 2, a widthwise elongate light source 3 is provided under the sheet material 1 which moves in a lengthwise direction as indicated by arrow "a", and across the upper surface of the sheet material 1, and close to the surface a widthways travelling narrow light beam LW is emitted by light beam emitting means 6, for instance, a gas LASER light source combined with converging optical means. A photoelectric transducer means 9 consisting of photoelectric transducer elements 91, 92 . . . 9n, is arranged over the path of the light beam LW in a position to cover the path of the light beam LW. A widthwise defect 5 such as a hole or a patch of dirt temporarily increases or intercepts at least partially the light from the light source 3 penetrating through the sheet material 1 as it moves on, thereby causing a change in the light incident upon some at least of the photoelectric transducer elements of the photoelectric transducer means 9, and consequently, generating an electric signal. On the other hand, a lengthwise defect 8 such as a wrinkle, a protuberance or a sticking substance intercepts totally or partly the light beam LW and reflects such light as the sheet material 1 moves on, thereby causing a change in the incoming light to the nearest photoelectric transducer element of the photoelectric transducer means 9, and consequently, generating an electric signal. In this particular example detection is effected either by the "Transmitted light mode" or the "Widthwise light beam mode" using common photoelectric transducer means.

In the embodiment shown in Figure 3, a sheet material 1 is driven in a direction indicated by arrow "a" by driving means not shown in the figure while passing over a roller 2. Accordingly, when no defects exist, the surface of the sheet material 1 assumes a partly Cyindrical shape on the roller 2. A pair of light beam emitting means 6 and 6', for instance, a pair of gas LASER light sources combined with converging optical means, is installed one adjacent each edge of the sheet

material 1 in such a manner as to emit a pair of narrow light beams LW and LW' which travel widthways in opposite directions but as close as possible to each other and also sheerly close to the surface of the sheet material 1 at the part where it passes over the roller 2. Over the paths of the light beam LW and LW' a photoelectric transducer means 9 is provided, the transducer consisting of photoelectric transducer elements 91, 92 .... 9n. Consequently, when lengthwise defects 8 and 8' such as wrinkles, protuberances or foreign matter, respectively, total or partly intercept the light from LW and LW' from the respective light beam emitting means 6 and 6', and thereby reflect at least a portion of the light beams reflected portions of the beams respectively strike the nearest photoelectric transducer elements of the photoelectric transducer means 9, and respectively causes the said transducer elements to generate electric signals.

In this embodiment two light beams LW and LW' are emitted in opposite directions and in very closely adjacent line from the their respective light source and therefore, even if the surface of roller 2 is not completely true, the light beams LW and LW' are able to travel very closely to the surface of the sheet material 1 on the roller 2, for at least a sufficient distance in the opposite directions that at least each half width of the sheet material 1 is subjected to accurate inspection. This arrangement is useful in a case where the central part of the roller is made slightly thicker than either of the ends for stability of the sheet material on the roller, or in the case where the roller is several metres long and therefore subject to slight sagging.

In the embodiment shown in Figure 4, a sheet material is driven in a direction indicated by arrow "a" by a driving means not shown in the figure, while passing over a roller 2. Accordingly, when no defects exist, the surface of the sheet material 1 assumes a partly Cylindrical shape where is passes over the roller 2. A narrow light beam LWM is emitted from a light beam emitting means 6, for instance, a gas LASER light source combined with converging optical means, to travel widthways sheerly close to and across the surface of the sheet material as that part where it passes over the roller 2. The said light beam LWM is modulated by a rotary chopper plate 61 which has several holes 62 and is rotated by a motor 54 through a belt drive 63. Over the path of the light beam LWM a photoelectric transducer means 9 is arranged consisting of photoelectric transducer elements 91, 92 .... 9n. Consequently, when a lengthwise defect 8 such as a wrinkle, a protuberance or a foreign body partly intercepts, the light beam LWM and thereby reflects at least a portion of the light, the reflected light strikes the nearest photoelectric transducer element of the photoelectric transducer means 9. As the light beam LWM is modulated, the reflected light is also modulated. Therefore, the photoelectric transducer means 9 is able to catch such modulated light even when the lengthwise defect 8 is very long, and accordingly the photoelectric transducer means 9 generates an A.C. electric signal which continues throughout the period that the long defect 8 is passing through the light beam LWM. Although one modulated light beam from a light beam emitting means is employed in this embodiment, a pair of light beams respectively emitted lengthwise in closely adjacent lines from each of two light beam emitting means provided just off each edge of the width of sheet material may be advantageously employed, as in the example shown in Figure 4, when the sheet material is unusually wide.

In the embodiment shown in Figure 5, a sheet material 1 is driven in a direction indicated by arrow "a" by a driving means not shown in the figure while passing over a roller 2. Accordingly when no defects exist the surface of the sheet material assumes a part-Cylindrical shape on the roller 2. A pair of light beam emitting means 6 and 6', for instance, a pair of gas LASER light sources combined with converging optical means, is installed just off each of the edges of the sheet material 1 in such a manner as to emit a pair of narrow light beam LWM and LW' which travel widthways in the opposite directions but as close as possible to each other and also sheerly close to the surface of the sheet material 1 at the part where it passes over the roller 2. The said light beam LWM is modulated by the rotary chopper plate 61 which has several holes 62 and is rotated by a motor 64 through a belt drive 63. The other light beam LW' is unmodulated. Over the path of the light beam LWM and LW' a photoelectric transducer means 9 is arranged consisting of photoelectric transducer elements 91, 92 .... 9n. Consequently when a lengthwise defect 81 such as a wrinkle, a protuberance or a foreign body totally or partly intercepts the light beams LWM and LW' and thereby reflects at least a part of the light beams, such reflected portions of light respectively strike the nearest photoelectric transducer elements of the photoelectric transducer means 9. As the light beam LWM is modulated, the reflected light is also modulated. Therefore, the photoelectric transducer means 9 is able to catch such modulated light even when the lengthwise defect 81 is very long and accordingly the photoelectric transducer means 9 generates an A.C. electric signal which continues throughout the period that the long defect 81 passes through the light beam LWM. On the other hand, the unmodulated light beam LW' infalliably catches a short lengthwise defect 82, such as a wrinkle, a protuberance or a foreign body whenever it

crosses the path of the light beam LWM, even when the light beam LWM is chopped off by the rotary chopper plate 61, thereby causing the generation of impulsive electric signal by the transducer means 9. Accordingly, by amplifying the output signal of the transducer by an A.C. amplifier, short lengthwise defects as well as long lengthwise defects, can be infallibly detected.

In the embodiment shown in Figure 6, a sheet material 1 is driven in a direction indicated by arrow " a " by a driving means not shown in the figure, while passing over the roller 2. Accordingly, when no defects exist, the surface of the sheet material 1 assumes a part-Cyindrical shape on the roller 2. A narrow light beam LW is emitted from a light beam emitting means now shown in the figure, for instance, a gas LASER light source combined with converging optical means, and travels widthways sheerly close to and across the surface of the sheet material 1 at the part where it passes over the roller 2. Over the path of the light beam LW a photoelectric transducer means 9 is arranged consisting of closely juxtaposed photoelectric transducer elements. Over another part of the sheet material 1 and elongate light source 3 is arranged which extends widthways across the sheet material 1 and emits a flat shaped light flux LR onto the surfce of the sheet material 1, and closely over the part of the surface of the sheet material 1 illuminated by the light flux LR is provided a photoelectric transducer means 4 consisting of closely juxtaposed photoelectric transducer elements. A lengthwise defect 8 such as a wrinkle, a protuberance or a foreign body which is short in the direction perpendicular to the said direction of movement of the material 1, does not cause sufficient change in the incoming light to the transducer elements of the photoelectric transducer means 4, to provide an adequate electric signal. On the other hand, the lengthwise defect 8 imparts a distinct effect to the narrow light beam LW emitted widthways to the sheet material 1, by totally or partly intercepting the light beam LW and reflecting such light as the sheet material 1 moves on, thereby causing a change in the incoming light to the nearest photoelectric transducer element of the photoelectric transducer means 9, and consequently, generating an electric signal. That is to say a detection signal by the " Widthwise light beam mode " is obtained from the photoelectric transducer means 9. A widthwise defect 5 such as a hole or a patch of dirt on the sheet material 1 causes in the transducer elements of the photoelectric transducer means 4 an impulsive change in the incoming reflected light caused by a temporary change of a part of the reflected light flux Lr when the defect passes under the photoelectric transducer means 4, and results in the generation of an electric impulse signal therefrom. That is to say, a detection signal by the " Reflected light beam mode " is obtained from the photoelectric transducer means 4.

An electrical circuit for processing signals from the transducers of this example is shown in the form of a block diagram in Figure 7, wherein numerals 41, 42, 43, 44, 45, 46, 47 and 48, respectively, indicate widthwise juxtaposed photoelectric transducer elements which constitute photoelectric transducers means 4. Numerals 91, 92, 93, 94, 95, 96, 97 and 98 respectively, indicate widthwise juxtaposed photoelectric transducer elements which constitute photoelectric transducer means 9. The photoelectric transducer elements 41 and 91, 42 and 92, 43 and 93 . . . . 48 and 98, constitute respective pairs for inspecting respective regions of the sheet material 1, and are connected with each other through variable amplitude pre-amplifiers 101 to 108 inclusive respectively. The junction points between the amplifiers 101 to 108 and the transducer elements 91 to 98 are separated into two groups of four junction points. Associated with each group are two differential amplifiers, 111, 112, and 113, 114. The first junction of a group is connected to one input terminal of a first one of the differential amplifiers, the second junction is connected to one input terminal of the second differential amplifier and the third and fourth junctions of the group are respectively connected to the other input terminal of each of the first and second differential amplifiers. The output signals from the differential amplifiers 111, 112, 113 and 114 are respectively fed to discriminators 121, 122, 123, and 124, for discriminating the level of the output signals and to convey only the signals having levels higher than a predetermined level to the output terminal 130. Respective output signals from the discriminators 121, 122, 123, and 124 are fed to a common output terminal 130. Accordingly, a detection signal is produced when an electric signal is generated by any one of the photoelectric transducer elements 41 to 48 paired with transducer elements 91 to 98, respectively, by a detection of a change in the incident light. As the photoelectric transducer means 9 for detecting defects by the " Widthwise light beam mode " generates neither electric signals nor noise when no defects exists, the photoelectric transducer means 9 has a very high signal-to-noise ratio. On the other hand, the output signal of the photoelectric transducer means 4 is accompanied by a considerable amount of noise, and therefore, its signal-to-noise ratio is not necessarily high, because the transducer means 4 is always receiving reflected light Lr from the surface of sheet material 1. The variable amplitude pre-amplifiers 101 to 108 are for mixing, after adjusting the output signals of the photoelectric transducer means 4 with the electric signals of the

photoelectric transducer means 9, so that the noise from the transducer means 4 will not be erroneously detected by the discriminators 121 to 124. Owing to the high signal-to noise ratio of the photoelectric transducer means 9, the mixing of the output signals of the transducer means 9 with those of the transducer means 4 is not liable to lower the detection ability of the transducer means 4. Accordingly, by amplifying the output signals of both transducer means 4 and 9 by means of the common differential amplifiers 111 to 114, it is possible to obtain from the output terminal 130 electric signals corresponding to all kinds of defects.

In the embodiment shown in Figure 8, a sheet material 1 is driven in a direction indicated by arrow "a" by a driving means not shown in the figure, while passing over rollers 2 and 2'. When no defects exist, the surface of the sheet material 1 assumes a part-Cyindrical shape on the roller 2. A narrow light beam LW is emitted from a light beam emitting means not shown in the figure, for instance, a gas LASER light source combined with converging optical means, to travel widthways sheerly close to and across the surface of the sheet material 1 at the part where it passes over the roller 2. Over the path of the light beam LW a photoelectric transducer means 9 is provided consisting of closely juxtaposed photoelectric transducer elements. Under another part of the sheet material 1, in this instance, a flat portion extending between the rollers 2 and 2', an elongate light source 3 is arranged to extend widthways across the sheet material 1 and emits a flat-shaped light flux LP onto the back surface of the sheet material 1. Over the sheet material 1 in a position opposite the light source 3 and close to the surface of sheet material 1, a photoelectric transducer means 4 is arranged consisting of closely juxtaposed photoelectric transducer elements. A lengthwise defect 8 such as a wrinkle, a protuberance or a foreign body does not give sufficient change in the light, incident upon the transducer elements of the photoelectric transducer means 4, and therefore, sufficient signal cannot be generated. On the other hand, lengthwise defect 8 has a distinct effect on the narrow light beam LW emitted widthways to the sheet material 1, by totally or partly intercepting and reflecting the light beam LW, as the sheet material 1 moves on, thereby causing a change in the light incident upon the nearest photoelectric transducer element of the photoelectric transducer means 9, and consequently, generating an electric signal. That is to say a detection signal by the "Widthwise ligh beam mode" is obtained from the photoelectric transducer means 9. A widthwise defect 5 such as a hole or a dirty patch on the sheet material 1 causes in the transducer elements of the photoelectric transducers means 4 an impulsive change in the incoming transmitted light due to a temporary increase or interception of a part of light LP penetrating through sheet material 1, when the defect 5 passes under the photoelectric transducer means 4. This results in the generation of an electric impulse signal therefrom. That is to say, a detection signal by the "Transmitted light beam mode", is obtained from the photoelectric transducer means 4. The electrical detection circuitry of this example can be arranged in the manner described for the embodiment shown in Figure 6 with reference to Figure 7.

As can be seen from the abovementioned descriptions of various embodiments, the method and apparatus for photo-electric inspection of sheet materials embodying the present invention are believed to be very useful in view of their ability of performing thorough detection of lengthwise defects such as wrinkles, protuberances, or foreign adhering on sheet materials, which as not hitherto been considered feasible by conventional methods and apparatus.

WHAT WE CLAIM IS:—

1. An apparatus for the photoelectric defect inspection of a moving sheet material in which defects are wrinkles, protuberances and sticking substances, comprising at least one light beam emitting means for emitting a narrow light beam which travels in a direction perpendicular to the direction of movement of the sheet material and sheerly close to the surface thereof; at least one photoelectric transducer for photoelectrically detecting total or partial reflection of the said light beam reflected at defective parts standing out from the surface of the sheet material; and at least one amplifier for amplifying the electric signals from the said photoelectric transducer.

2. An apparatus as claimed in Claim 1, wherein a pair of light beam emitting means are provided for emitting two adjacent narrow light beams the two light beam emitting means being arranged in opposite positions one off each edge of the width of the sheet material.

3. An apparatus as claimed in Claim 1 or Claim 2, wherein the, or at least one of the narrow light beams is a modulated light beam and the said amplifier is an A.C. amplifier.

4. An apparatus as claimed in Claim 1, wherein a pair of light beam emitting means are provided respectively for emitting a modulated narrow light beam and an unmodulated narrow light beam whose paths are close to each other, and the said amplifier means are A.C. amplifiers.

5. An apparatus as claimed in any one of Claims 1 to 4, wherein the photoelectric transducer extends widthways over the width of the sheet material and the said light beam is

interposed between the sheet material and the transducer means.

6. An apparatus as claimed in Claim 5, wherein an additional light source extending widthways relative to the sheet material is provided in a position corresponding to and opposite the photoelectric transducer means, so that the sheet material is interposed between the light source and the transducer means.

7. An apparatus as claimed in Claim 1, wherein a first light beam emitting means consists of a LASER light source, and a converging optical means, and wherein a second light source extends widthways to the sheet material and a second photoelectric transducer means extends widthways to the sheet material for receiving light from the said second light source reflected by the sheet material, signal mixing means for mixing electric signals from the said first and second photoelectric transducer means after adjusting the same to a suitable amplitude, and discriminating means for discriminating level of the mixed signals and generating defect signals.

8. An apparatus as claimed in Claim 1, wherein a first light beam emitting means consists of a LASER light source and a converging optical means, and wherein a second light source extends widthways relative to the sheet material, having a second photoelectric transducer means extending widthways to the sheet material for receiving light from the said second light source penetrating through the sheet material, signal mixing means for mixing electrical signals from the said first and second photoelectric transducer means, after adjusting the same to suitable amplitude and discriminating means for discriminating the level of mixed signals and generating defect signals.

9. A method for photoelectric defect inspection of a moving sheet material in which the defects are wrinkles, protuberances or sticking substances, wherein at least one narrow light beam is emitted in a direction perpendicular to the direction of movement of the sheet material and sheerly close to the surface thereof, and wherein light from said light beam, reflected by defective parts standing out from the surface of the sheet material, is detected.

10. A method of photoelectrically inspecting sheet material substantially as hereinbefore described with reference to any one of the figures of the accompanying drawings.

11. Apparatus for the photoelectric inspection of sheet material substantially as hereinbefore described with reference to and as illustrated in any one of the figures of the accompanying drawings.

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Sheet 1

FIG. 1.

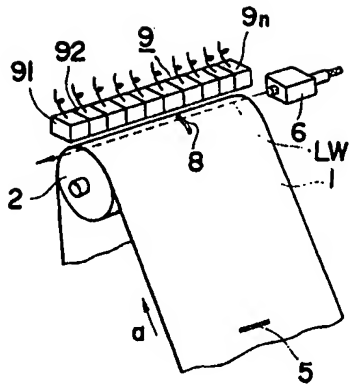


FIG. 2.

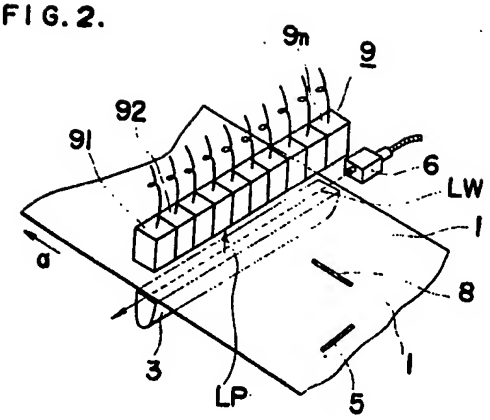


FIG. 3.

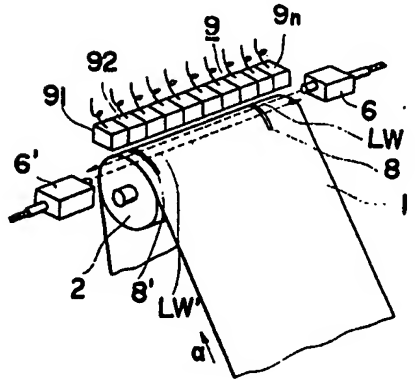


FIG. 4.

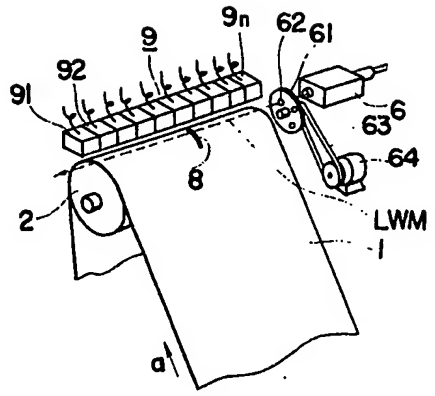
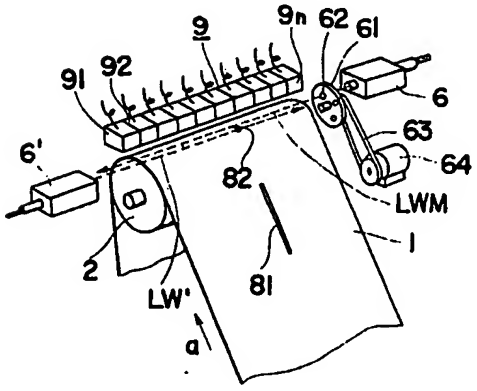

9n
62
61
9
92
91
6
63
64
8
2
LWM
1
a

FIG. 5.


9n
62
61
9
92
91
6
63
64
6'
82
LWM
1
2
81
LW'
a

1217642 COMPLETE SPECIFICATION
4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 4

FIG. 6.

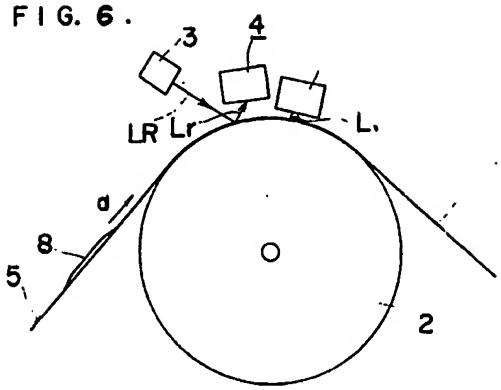


FIG. 7.

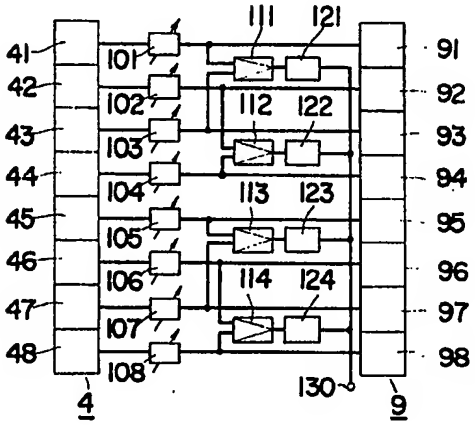


FIG. 8.